FEATURES OF THE STRUCTURE OF A STRONG-CURRENT ELECTRON BEAM PASSING THROUGH A LOW-PRESSURE GAS

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Experimental results are presented on the passage of strong-current electron beam through a low-pressure gas. It is shown that gas focusing is observed at a pressure 0.4 — 1 Torr. Characteristic singularities of the beam structure are observed at 0.1 — 1 Torr. The experiments were performed at electron energies 300 and 700 keV.

We used the strong-current "Impul's" accelerator to perform experiments on the passage of electron beams through gases of different densities under two operating conditions, with E_1 = 300 keV and E_2 = 700 keV. The experimental setup is shown on Fig. 1. The "Impul's" accelerator consists of an Arkad'ev-Marx generator, a double shaping line, a transforming line, and a cold-cathode electron gun. The maximum electron energy is 700 keV, the current is 30 kA, and the pulse duration is 50×10^{-9} sec. The construction of the accelerator was described in [1, 2]. The drift chamber, which follows the electron-gun block, is a glass tube approximately 2 m long. Its internal surface is covered with a stainless-steel grid. The electrons were extracted from the electron gun into the chamber through a titanium foil 50 μ thick. During the course of the experiment, we registered the magnitude and duration of the current pulse, the diode gap voltage, and also the optical and x-radiation and the total luminosity of the gas in the chamber.

Figure 2 shows photographs of the gas following passage of a beam through the chamber, under the two operating conditions of the apparatus and under different conditions of beam transport. The glow region

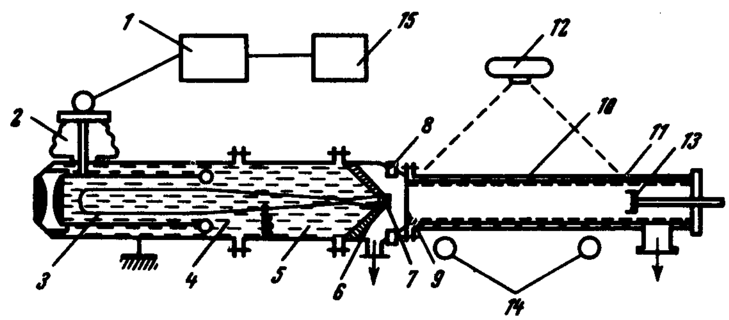

Fig. 1. Schematic diagram of experiment: 1 — Arkad'ev-Marx pulsed-voltage generator, 2 — charging insulator, 3 — double shaping line and discharge gap for its switching, 4 — transforming line, 5 — dielectric (glycerin, ε = 44), 6 — insulator of electron gun, 7 — cathode of electron gun, 8 — shunt for current measurement, 9 — titanium foil (60 μ), 10 — glass drift chamber, 11 — conducting liner, 12 — photographic camera, 13 — movable Faraday cylinder, 14 — radiation receivers for the visible and x-ray bands, 15 — accelerator control block.

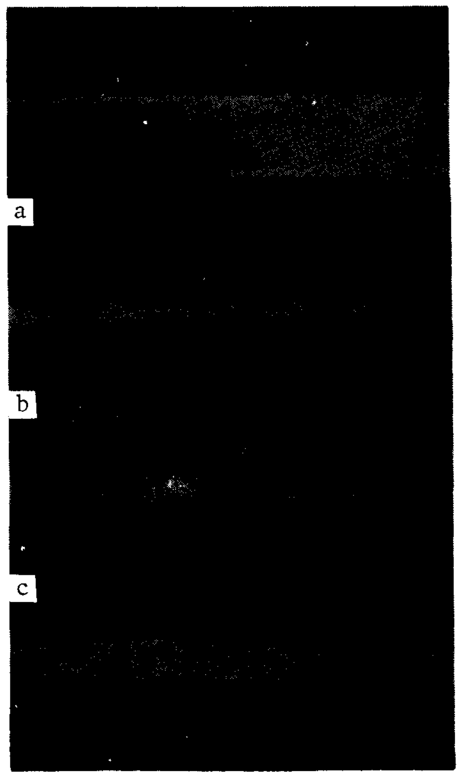

Fig. 2. Glow of gas (air) following passage of the beam electrons through the drift chamber:
a) E_1 = 300 keV, P = 10^{-2} Torr;
b) E_1 = 300 keV, P = 10^{-1} Torr;
c) E_1 = 300 keV, P = 7×10^{-1} Torr;
d) E_2 = 700 keV, p = 7×10^{-1} Torr.

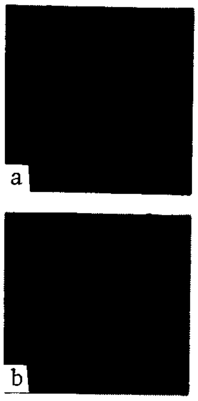

Fig. 3. "Autograph" of the beam on lead plates.

of the gas is determined by its pressure and composition, and also by the beam energy. It is seen from Fig. 2a that at a beam energy E_1 = 300 keV and a pressure 10^{-2} Torr the beam can hardly pass through, owing to the Coulomb repulsion, and the gas glows only at the entrance to the chamber. With increasing pressure, the shape and the dimensions of the glow region are significantly altered. In the pressure range 0.1 — 0.4 Torr, a bright filament is observed along the entire chamber, with a diameter ∿ 3.5 cm.

A characteristic new feature of the structure of the beam in this region, not observed in the other experiments [3 — 5], is the presence of bright spikes or strips making an acute angle with the principal filament (Fig. 2b). At E_1 = 300 keV, I_{max} = 11.7 kA and P = 0.1 Torr (gas, air), the inclination angle of the strips is 15 — 20°. The average distance between them is 6 cm. The strips were observed up to 50 cm from the foil and from the entrance of the beam into the chamber. A possible explanation for the currents and laws governing the locations of these strips is based on allowance for the interaction of the beam with its self-field [1)].

At a pressure 0.4 — 1 Torr, we observed clearly pronounced effects of gas focusing (Fig. 2c), some of which were noted in [3 — 6]. The beam in the chamber was focused to a diameter ∿ 1 cm at a beam glow diameter ∿ 4 cm at the entrance. The effects of focusing of the beam were confirmed also by the picture produced by the beam on lead plates placed in the path of the beam (Figs. 3A, B). The distance λ over which the beam becomes focused under our experimental conditions can be estimated from the formula

$$\lambda = (2\pi\gamma m\beta^2 c^3)^{1/2}[e(\beta^2 + f - 1)]^{-1/2} j^{-1/2},$$

which gives a value of 26 cm. Here N_e and N_i are the linear densities of the beam electrons and of the ions, $f = N_i/N_e$, and j is the current density. The experimentally obtained value is 30 cm. At pressures near 1 Torr one observes the onset of beam instability, such as bending, a tendency to twisting, etc.

At a beam electron energy E_2 = 700 keV (second operating regime of the accelerator), in different gases (He, Ar, Xe, air), the beam behavior described above is also observed on passing through the low-pressure gas, but the characteristic spikes or strips do not appear. The onset of instability leads additionally to a transverse displacement of the beam (Fig. 2d).

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1) The corresponding theory proposed by K. V. Khodataev is described in [6].

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